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Quarterly Report for High NA Optics Development: Q3-1999 International Sematech project LITH 112

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Quarterly Report for High NA Optics Development: Q3-1999
International Sematech Project LITH 112

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Executive Summary

This quarterly report provides a status update for each of the milestones for the International Sematech project on the development of high-NA optics for a small-field EUVL exposure tool. The optical design has been completed, which employs two aspheric mirrors yielding diffraction-limited imaging within a 600 μm x 200 μm field with a numerical aperture of 0.3 and a 5x reduction. Preliminary aerial image calculations show good resolution of 30nm features with partially coherent illumination. Contracts have been awarded for the fabrication and multilayer coating of the mirror elements and a detailed specification package has been generated for one of the mirror substrates (M1). Metrology instrumentation is being assembled and fabrication has been initiated on M1. Key progress includes the design and fabrication of kinematic mounting fixtures that enable the vendor to perform interferometry in a geometry compatible with PO Box fixturing. The first substrate is proceeding according to schedule, with delivery expected in December 1999.

Summary of Progress

Milestone 1: Award contract for the fabrication and testing of two aspheric mirrors

A contract was placed with Carl Zeiss (Oberkochen) for the fabrication and testing of substrates for the High NA Camera. The schedule being followed by Zeiss begins with the fabrication of the primary mirror, with completion in Q4 1999. The vendor plans to achieve convergence to their metrology to a tolerance of 0.25 nm rms by November 30, 1999. Metrology data is scheduled to be delivered prior to the December NGL meeting. Polishing will continue in December while Zeiss augments their interferometry to assess accuracy.

Zeiss will procure material and begin fabrication of the secondary (M2) during Q4 1999, but will not complete it until Q2 2000. One of the key tasks to be completed during Q1 2000 is the conversion of their interferometry set-up to accommodate the M2 mirror. Preliminary technical drawings for the M2 substrate have been prepared and transmitted to Zeiss.

Milestone 2: Award contract for the multilayer coatings

Zeiss has chosen to not bid on the multilayer coating of the substrates. Coating is now planned to be done at LLNL using the same approach that is currently employed for the ETS elements. The current plan is to coat both of the elements (M1 and M2) during the same coating run in order attain an optimal wavelength match. Preparation for the coating process will begin in Q4 1999.

Milestone 3: Optical design package for EUV imaging system employing two aspheric mirrors

A report on this milestone is complete and is being submitted to Sematech (Neil Wester). This simple high NA optical system, diagrammed in Figure 1, is designed to be used in a microstepper and makes use of the "equal radii" concept to correct field curvature over a 600 μm x 200 μm field at the wafer. The projection system is designed to work at a reduction ratio of 5:1. Two aspheric mirrors are used in a coaxial, obscured configuration to achieve the high numerical aperture (NA) of 0.30. The area obscuration is carefully limited to less than 10% of the exit pupil area, allowing the optical system to achieve sub-30 nm resolution with partially coherent illumination. The system is compatible with either a reflection or transmission mask, enabling two distinct modes of operation. To use a reflection mask, the mask plane is itself is tilted to allow the illumination to enter the projection optics. There is a corresponding tilt to the wafer plane that allows the design to recover most of its nominal performance. Diffraction-limited performance across the image field is achieved in either imaging mode. Using a transmission mask, the field composite RMS wavefront error is 0.28 nm (0.021λ, λ= 13.4 nm). With a reflection mask, the field composite RMS wavefront is 0.42 nm (0.031λ).

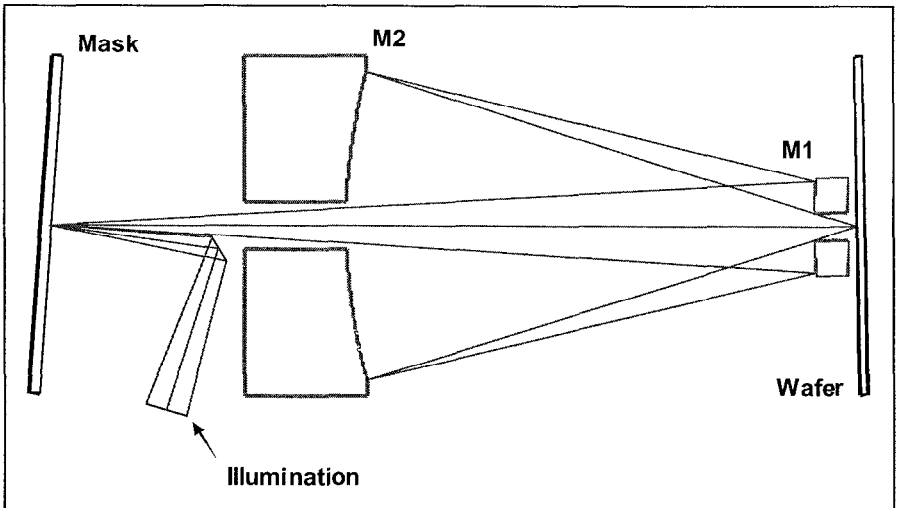

Figure 1. Schematic of High-NA Camera for the Micro Exposure Tool (MET).

Distortion with a transmission mask is small, controlled to less than 2.25 nm in the corners of the rectangular field. This residual distortion is small enough to consider using this projection system as a microscanner, rather than as a microstepper. The magnitude of the distortion grows rapidly with a reflective mask since it must be tilted (4.0°). Anamorphic and keystone distortion dominate throughout the field, with a maximum radial error in image placement of 498 nm. However, the optical design meets our objective of providing well-corrected imaging using a reflective mask in a stepping mode.

In addition to analysis using traditional optical metrics, an initial analysis of the partially coherent imagery was also performed. Specifically, a focus-exposure matrix (FEM) and corresponding CD process window were generated. With an exposure variation and CD variation of ±10%, the depth of focus was found to be ~ 0.2 μm. At best focus, the design can tolerate an exposure variation of +20%/-15%, within the limits of a ±10% CD variation. The CD uniformity across the field for both dense and isolated features was estimated conservatively from 2D aerial image profiles to be better than ±2.5% for 30 nm features, which is suitable for a research tool. Three-dimensional partially coherent aerial images of a sample test geometry, containing dense features, isolated features, isolated elbows and contacts, demonstrate that the MET optical system will print a variety of features to the ultimate resolution limit of 30 nm without limitation.

Milestone 4: Specification package for the individual polished mirror substrates
4a: M1 4b: M2

The design of the M1 substrate is complete and Zeiss has initiated manufacturing. Completion of this design required the concurrent design of the fixturing hardware for mounting the element into the vendor's interferometer. A drawing of the M1 substrate is shown in Figure 2. This step enabled the design of the mounting and datum surfaces on the element. Also, a finite element analysis was performed to determine the optimal thickness, which involved a trade-off between a) making the substrate thicker to gain stiffness; and b) making the substrate thinner to maximize the separation between the wafer plane and the back surface of the element. A satisfactory compromise was reached such that both requirements are satisfied.

A report and design drawing for Milestone 4a is being submitted to Sematech (Neil Wester) on 10/8/99. The engineering analysis for this M1 and the initiation of manufacturing was completed by the scheduled date of 9/24/99.

Preliminary designs have been developed for the secondary (M2). These early designs will enable the vendor to purchase material. The final design will be completed in Q4 1999. The completion of this milestone will ideally require a mature design concept for the PO Box structure and actuation strategy for alignment.

Milestone 5: Predicted aerial images from camera

Preliminary calculations of aerial images have been completed and are included in the report for Milestone 3. This analysis will continue until completion in Q4 1999. We request extending the delivery date of this milestone from the scheduled date of 10/22/99 until 11/19/99.

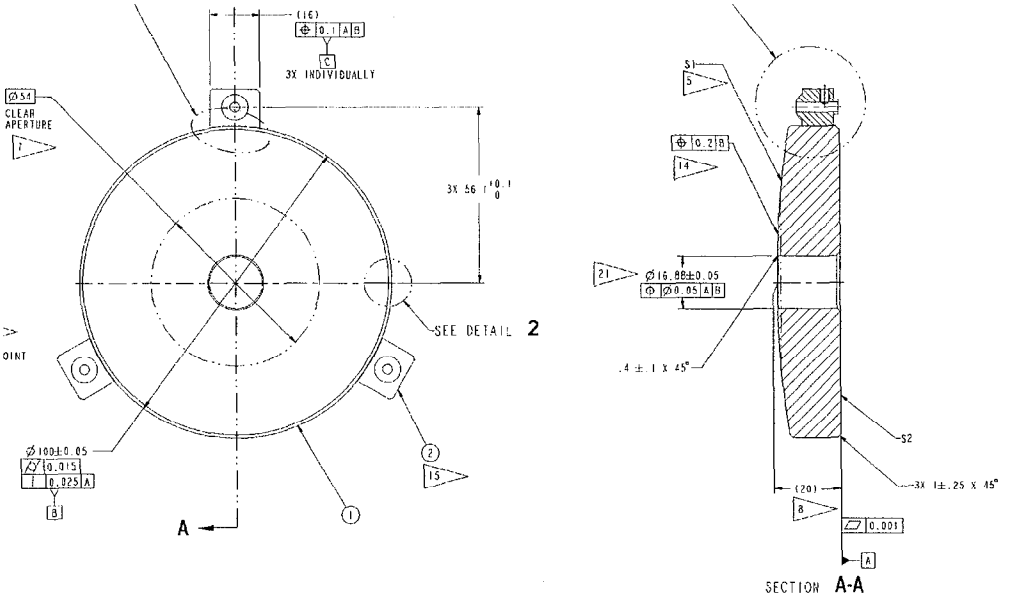

Figure 2. The main views from the M1 optic drawing.

Milestone 6: Specification package for the multilayer coatings

During the completion of the optical design analysis, it was verified that high quality images could be attained using Mo/Si multilayers. The completion of Milestone 6 will result in a tolerance analysis for coating uniformity. The coating group will use this information in selecting a coating strategy and in planning surrogate deposition experiments.

We anticipate completion of this task on the scheduled date of 11/19/99.

Milestone 7: Prediction of printed images of characteristic mask defects
7a: Preliminary 7b: Final

The prediction of the printed images has commenced and we plan to submit a preliminary report of our calculations on the scheduled date of 11/30/99. Initial calculations are included in the report for Milestone 3.

Milestone 8: Validation of vendor metrology
8a: Validation Plan 8b: Validation Results

We have assembled a preliminary plan for the assembly of a Phase-Shifting Diffraction Interferometer (PSDI) for testing the M1 mirror at LLNL. This approach is the same method for validating the manufacturing of elements for the ETS. The current plan addresses: 1) the design and fabrication of a converging lens with low "retrace" errors that matches the NA of the M1 element; 2) the design and fabrication of a lens for imaging the interference fringes onto the CCD camera; 3) an error analysis of the system; and 4) miscellaneous mounting and alignment hardware. The continued planning of this task is

intended to determine the optimum means of adapting existing mechanical elements from the current ETS PSDI.

We are planning a Conceptual Design Review of the metrology plan during November anticipate that the Validation Plan will be completed by the current schedule date of 11/30/99.

Milestone 9: Delivery of the polished substrates
9a: M1 9b: M2

Carl Zeiss has submitted a schedule that indicates that 0.25 nm rms precision will be achieved by 11/30/99. In support of this, Zeiss has 1) acquired material for M1, spares, and metrology reference spheres; 2) LLNL has designed and fabricated fixturing hardware for the M1 and its interface to the Zeiss interferometer; 3) LLNL has begun bonding mounting "buttons" onto the Zerodur™ M1 substrates; 4) LLNL has shipped mounting hardware and bonded substrates back to Zeiss; and 5) Zeiss is constructing metrology to support the testing of the elements. Figure 3 shows a photograph of a surrogate substrate inserted in precision fixturing for demonstrating the bonding of mounting buttons onto the primary substrate. Figure 4 is a photograph of a surrogate with buttons mounted on the metrology fixture that has recently been delivered to Zeiss. We anticipate that the planned completion dates for this milestone will be met.

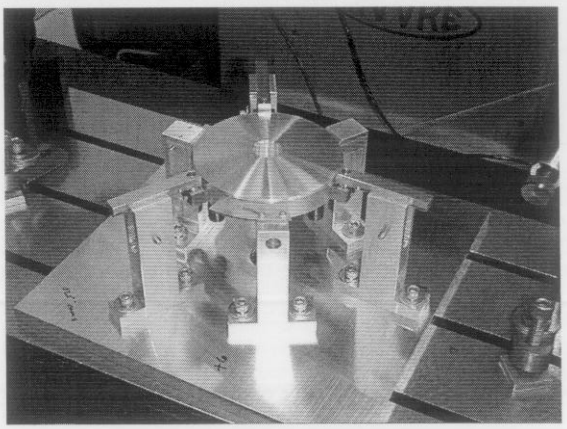

Figure 3. M1 surrogate within the precision tooling for bonding mounting buttons onto the outer datum surface.

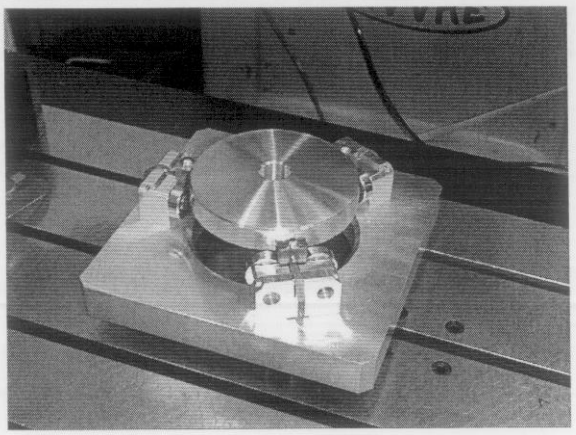

Figure 4. M1 surrogate mounted on the precision fixture to be used within the vendor's interferometer.

Milestone 10: Delivery of the multilayer coated substrates

Planning has begun for this task. However, hardware preparation will not begin until Q1 2000 when the coating specifications are complete. We anticipate completing this task on the scheduled dates.

Milestone 11: Multilayer coating metrology

We are currently considering fixturing requirements for performing reflectometry at the LBNL Advanced Light Source. The current M2 substrate design is larger than the largest ETS substrate, which may pose clearance issues in the chamber. Although the task is not scheduled until Y2000, we are discussing M2 design details and fixturing plans with LBNL to meet compatibility requirements.

Milestone Chart

M/S	Description	Task Section	Deliverable Section	Due Date
1	Award contract for fabrication and testing of two aspheric mirrors; Prepayment to vendor to initiate work.	3.1.6	8.1.6	8/31/99
2	Award contract for multilayer coatings.	3.1.7	8.1.5	8/31/99
3	Optical design package for EUV imaging system employing two aspheric mirrors	3.1.1	8.1.1	9/24/99
4	Specification package for the individual coated mirror substrates. Mx a (x=1,2): Preliminary Mx b: Final	3.1.4	8.1.4	M1 a: 9/24/99 M2 a: 11/30/99 M1 b: 9/24/99 M2 b: 12/22/99
5	Predicted aerial images from camera	3.1.2	8.1.2	10/22/99
6	Specification package for multilayer coatings	3.1.5	8.1.5	11/19/99
7	Prediction of printed images of characteristic mask defects. a: Preliminary b: Final	3.1.3	8.1.3	a: 11/30/99 b: 12/22/99
8	Validation of vendor metrology. a: Validation plan b: Validation results	3.1.8	8.1.7	a: 11/30/99 b: 5/12/00
9	Delivery of polished substrates. a: M1 substrate b: M2 substrate	3.1.6	8.1.6	a: 12/31/99 b: 5/12/00
10	Delivery of multilayer coated substrates	3.1.7	8.1.8	6/9/00
11	Multilayer coating metrology	3.1.7	8.1.8	6/23/00

Auspices

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